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instruction manual

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NORTH ATLANTIC
industries, inc.

Model 301

phase angle voltmeters

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OPERATING AND INSTRUCTION

MANUAL FOR

MODEL 301 BROADBAND

PHASE ANGLE VOLTMETER

Patents are Pending for all Circuits
Used in This Instrument

NORTH ATLANTIC INDUSTRIES, INC.
Plainview, New York

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Printed in U.S.A.

Serial 4705

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SECTION I

SPECIFICATIONS

Voltage Range: Full scale 1 millivolt to 300 volts in 12 ranges.

Frequency Range: Phase Sensitive and Phase Angle:
10~ to 100KC (selected in half-decade steps by front panel switch).

Total: 10~ to 100KC.

Fund: Any frequency within band of 10~ to 100KC determined by plug-in filters available to cover band.

Phase Accuracy: ±0.° 31.6 cps to 31.6KC ±.4°
10 cps - 31.6 cps ±.8°
31.6KC - 100KC ±.8°
(when ZERO and EQUAL controls are properly set)

Note: For sweep application where ZERO and EQUAL controls are not set, phase may vary by 3° over each one-half decade frequency band.

Voltage Accuracy: ±2% full scale, all modes, over whole band.

Calibration: Meter: Zero center, 3-0-3 and 10-0-10 scales, plus log scale calibration in db.

Phase Angle: Dial 0-90° in 0.2° divisions. Four position quadrant selector covers 0-360° non-ambiguously.

Input Impedance: Signal: 10 megohms, 25 uuf, all ranges.

Reference: 10 megohms, 25 uuf.

Reference Level: Variable from 0.15 to 130 volts by Hi-Lo selector and vernier.

Overload: Overload lamp lights at input 10X full scale setting.

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Noise:	Less than 10 microvolts in Total and Fund. modes.
Nulling Sensitivity:	Less than 2 microvolts in phase sensitive mode.
Harmonic Rejection:	Low pass sharp cut-off plug-in filters (50 ~ to 10KC range) rejection of greater than 30db outside pass band. By judicious choice of one of 22 standard available filters this may be increased to 50db for any specific frequency. In addition, detector characteristics reject all even order harmonics as well as odd order harmonics in inverse proportion to the harmonic order.
Non-Coherent Signal Rejection:	For frequencies removed from signal frequency by approximately 5~ or more (effective pass band of meter movement), the response is essentially nil for levels up to 10 times the value of the full scale in use.
Power:	115 volts ±5%, 50 to 400~.
Size:	Panel: 7" height x 19" width x 1/8" thickness. Depth 10 1/16".

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SECTION II

GENERAL DESCRIPTION

1. General Description.

The Model VM-301 Broadband Phase Angle Voltmeter combines in one instrument the ability to measure both phase angle and magnitude of complex AC signals and their vector components with respect to a reference voltage. Designed to operate over the frequency range from 10~ to 100KC, it utilizes passive phase shifter circuits (patents applied for) to assure high accuracy over this spectrum. Because of these broadband characteristics, the Model VM-301 fills a long existing need for a null and phase meter for measurements in which signal frequency itself can be a variable. Through its use, measurements of AC ratios, phase angles, and related quantities can be made with non-stable frequency sources, or while sweeping frequency to determine phase versus frequency characteristics.

Front panel controls permit instantaneous selection of range, function and frequency band. As a null meter, the instruments' 2 microvolts sensitivity permits high resolution ratiometry results. As a phase meter, angles are read on a high resolution, parallax-free scale, calibrated in 0.2° increments. For highest accuracy, two simple push and set controls permit trimming to the existing source frequency to achieve better than 0.2° accuracy. Plug-in, interchangeable harmonic filters are available on the band of 50~ to 10KC.

2. Applications.

A. Phase Sensitive Null Indicator.
B. Measures separately the in-phase and quadrature components of an AC signal.
C. Measures phase angle shift in all AC systems.
D. Sensitive AC voltmeter.
E. Testing of Servos, Computers, Synchros, Resolvers, Inductosyns.
F. Precise AC Ratiometry.
G. Phasing of Servo Motors, Chopper Amplifier, Magnetic Amplifier.

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H. Measuring of both torque and non-torque producing signals.
I. Align carrier amplifier and notch networks.
J. Impedance meter.
K. Power factor meter.

3. Power Line Voltage and Cable.

A. The instrument is normally wired for 115 volt operation. If it is desired to operate the instrument from a 230 volt source, refer to the transformer conversion data on the schematic diagram for the correct procedure. Be sure to use the proper fuse in each operation.

115 V Source - 3 Amp Fuse.
230 V Source - 1 1/2 Amp Fuse.

B. All electrical grounds are floating in respect to chassis. The instrument is supplied with a three prong power plug, the round pin is wired to the chassis. Common grounding of power, chassis, and circuit ground is accomplished by means of a link on the signal input terminals. The instrument may be operated either floating or with common ground.

4. Accessories

A. Filters of the plug-in type can be supplied in the ranges of 60~ to 10KC, for harmonic rejection in both signal and reference channels. Filters may be plugged into unit and switched in and out of circuit with switch on front panel. For operation using filters refer to Section IV, Par. 6.

B. Signal Modules.

P-201 Reference Isolation Module is intended for applications which require that the external reference signal generator be isolated from the Reference and/or Signal Channels of the measuring instrument. It will eliminate errors due to extraneous currents in the signal circuits from common ground connections. The module plugs directly into the banana jacks of the reference input on the

North Atlantic Phase Angle Voltmeter.

P-202 Summing Module is a precision plug-in resistive summing network recommended for use in AC Ratiometry measurement where the test piece polarity precludes the use of a bridging transformer. It is also recommended for minimizing in-phase ratio errors resulting from quadrature current flowing in reactive elements in the null circuit. The three standard values listed are most widely used, but units are available in other resistance values from 10K to 2.0 megohms. The specified degree of match, between each resistive half, includes both the real and active components at the specified frequencies.

P-203 Universal Isolation is a plug-in transformer module designed for precision bridging and signal isolation application in phase sensitive AC voltage measurements and AC Ratiometry. The unique shielding design incorporates special separate shielding of the primary and secondary windings. It can be used as a precision bridging transformer for establishing null voltages in critical AC measurements. Used as a signal isolation transformer, it allows the signal source to be isolated from the measurement instrument and power ground without detriment to the measurement accuracy. This design provides absolute minimum coupling of the primary common-mode signal into the secondary winding.

CAUTION

THE PROPER APPLICATION OF THESE MODULES EXTENDS THE VERSATILITY OF AC PHASE DETECTION AND RATIOMETRIC INSTRUMENTS TO A WIDE RANGE OF MEASUREMENT TASKS IN ACTUAL SYSTEMS WHERE GROUND LOOPS AND EXACT MEASUREMENT CONDITIONS CANNOT BE DEFINED OR PREDICTED IN ADVANCE. THESE PRECISION MODULES ARE DESIGNED TO BE UNIVERSALLY USED WITH ANY AC RATIOMETRIC AND PHASE DETECTION INSTRUMENTS PROVIDED WITH STANDARD 3/4" SPACED BANANA JACKS SUBJECT TO FREQUENCY RESPONSE.

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SECTION III

CONTROLS, DISPLAYS, INPUTS

1. On-Off Switch

This toggle switch energizes the primary circuit of the power transformer. With the switch "On" the voltmeter's face will be illuminated.

2. Range Switch

This rotary switch selects the proper multipliers for the desired voltage range. The range switch indicates both the full scale voltage and the db level at each position.

3. Function Selector

The "Function Selector" is used to select the desired mode of operation for the instrument. In the four Phase Angle Voltmeter position, the instrument is connected so that it may read a voltage $E \cos \phi$, where ϕ is defined as the angle between the signal vector and the reference vector. The "Function Selector" then selects the quadrant over which the calibrated phase shifter will operate. Thus, the total angle shifted in degrees will be either 0°, 90°, 180°, or 270°, plus the reading of the phase dial.

In the "VTVM" position the instrument functions as a standard voltmeter. With the filter switch in the "Filter Out" position, the voltmeter will read the entire input signal, including harmonics. With the filter switch in the "Filter In" position the instrument will read the total vector voltage of the fundamental signal.
(Note: See Filter Switch Section III Par. 5 and Filter Operation Section IV, Par 6).

4. Frequency Selector

This dual concentric switch selects the desired frequency range in half decade steps. The entire frequency band is divided into two spectrums, 10~ to 1KC and from 1KC to 100KC. The large drum dial selects either the high or

low spectrum. The small pointer knob then selects the proper half-decade step.

5. Filter Selector

This toggle switches the harmonic attenuation filters either into or out of the signal and reference channel. (Note: See Section IV, Paragraph 6 for Selection and Operation of Filters).

6. Reference Level Switch and Control

This switch and the associated potentiometer represents the Reference Channel Range Selector, allowing the wide range of Reference (.15V to 130V) to be used. This is not a calibrated control and for proper adjustment of the Reference Hi-Lo and Level Control, see Reference Level Meter Section III, Par. 11.

7. Zero Switch, Equal Switch, and Controls

Combined, these four controls perform the necessary trimming of the two Amplifier Channels and Phase Shifter Networks to align the instrument for accurate phase measurements ($\pm 0.2^{\circ}$) at a specified frequency. (See Phase Angle Measurement, Section IV).

8. Filter Amplitude Adjustment

This control is mounted on the right side of the slide draw behind the voltmeter and is used when changing filters to compensate for the insertion loss associated with filters. (See Filter Operation, Section IV, Par. 6).

10. Voltmeters

The meter is a zero center D.C. milliameter calibrated to read the RMS value of a sine wave. For "STD VTVM" reading, the needle deflects to the right. For "Phase Angle VTVM" reading, the meter deflection may be to the left or right. Calibrated Zero center 3-0-3 and 10-0-10 scales, plus log scale calibrated in db (See Section IV).

CAUTION: BY ITS NATURE, THE INSTRUMENT IS REQUIRED TO HANDLE INPUTS CONSIDERABLY IN EXCESS OF ITS FULL SCALE READING. DAMAGE CAN OCCUR IF THE SIGNALS ARE APPLIED IN A MANNER WHICH WILL DRIVE THE NEEDLE HARD AGAINST THE STOPS. THEREFORE, ALWAYS APPROACH A MEASUREMENT FROM THE LEAST SENSITIVE POSITION AND RETURN TO THIS POSITION BEFORE MAKING CIRCUIT ADJUSTMENTS.

11. Reference Level Meter

This zero suppressed meter indicates the reference voltage level in the phase shift networks. This is used for phase reading and trimming purposes. (See Reference Level Adjustment, Section IV).

12. Phase Dial

This dial is calibrated to read the degrees of Phase Shift introduced by the calibrated phase shifter networks with the particular quadrant selected by the "Function Selector." The dial is calibrated 0-90° in 0.2° graduations. Positioning of this dial is critical and for this reason should it be necessary to repair or replace, the procedure under "Phase Angle Dial Positioning" of Section VI should be followed.

13. Overload Indicator

The lamp marked "Overload" lights whenever a prescribed signal level is exceeded. As the signal approaches the overload condition, the lamp will blink. A steady glow indicates overload condition. This indication warns of

impending amplifier overload and the attendant inaccuracies which will occur when large saturating signals are present. The overload indicator is factory set at ten (10) times full scale.

14. Inputs-Terminals

Five terminals are provided on the front panel for connection to external test circuits. Terminals for both the signal and reference inputs are colored Black for circuit ground and colored Red for the high side of the input. These posts which are on a standard 3/4 inch spacing will accomodate banana plugs, wire, or alligator clips.

A third terminal is provided on the signal input for connecting circuit ground to chassis ground. As the voltmeter circuit grounds are floated above chassis, a link is provided between the metal terminal and the ground (Black) terminal of the signal input to allow maximum flexibility of connections. Great care should be given to grounding methods used to avoid ground loops and stray fields.

CAUTION: MAXIMUM SIGNAL INPUT MUST NOT EXCEED 1,000 VOLTS AND MAXIMUM INPUT REFERENCE MUST NOT EXCEED 600 VOLTS (COMBINED PEAK AC & DC LEVELS).

HIGHER VOLTAGES WILL BREAK DOWN THE INPUT CAPACITORS IN THE INSTRUMENT.

15. Filters

Harmonic attenuation filters can be supplied in single frequency pairs for a specified band of frequencies in the range from 60~ to 10KC. These are plug-in units located behind the voltmeter and are accessible by loosening the thumb screw below the meter and pulling the meter draw assembly forward. (See Filter Operation, Section IV, Par 6.).

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16. Fuse

The Fuseholder mounted on the back of the instrument will accept either a 3 amp or 1 1/2 amp Fuse, depending upon the line voltage. (See Power Line Voltage, Section II).

SECTION IV

OPERATION

Operation

The instrument as received from the factory should indicate zero before being turned on. If it does not, reset the meter to read zero by means of the adjusting screw near the bottom in the rear of the meter. To accomplish this, loosen quarter turn thumb screw directly below the meter, pull meter draw chassis forward. This adjustment must be done with the power off and with the instrument in a horizontal or near horizontal position.

With the instrument plugged into the proper power source, turn the toggle switch to "ON." Allow the instrument to warm up about 15 minutes for stable operation. For precision phase measurements, additional time should be allowed.

CAUTION: BEFORE MAKING PHASE OR VOLTAGE MEASUREMENTS, REVIEW SECTION ON GROUNDING TECHNIQUES IN APPLICATION NOTES.

1. To Measure Voltage

Set the Volts-db (range) switch to the appropriate scale and the Function Selector to the "VTVM" position. Connect the voltage to be measured to the Signal Input Terminals. Read the voltage from either the 0-10, 0-3 or db scales, using the proper scale factor as determined by the range selector position.

With the Function Selector switch in the VTVM position and the Filter switch in the OUT position, the voltmeter operates as a standard AC VTVM. This AC VTVM reads the total vector voltage at any frequency and all harmonics. With the FILTER switch in the IN position and with the proper filters plugged into the instrument, the voltmeter will read only the fundamental voltage within the range of the filter.

Notice that with no input to the instrument, the meter needle deflects on the low ranges. This condition is normal and represents a true measurement of the stray fields capacitively coupled to the input. Shielding the input will reduce this deflection to near zero.

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Measurements made on high impedance circuits require that special attention be paid to capacitive as well as inductive pickup. Twisted and/or shielded cable will reduce the effect although the cable capacity could serve to load the source.

Care must also be taken to ensure that ground loops do not exist by virtue of the signal and reference grounds which will result in erroneous readings.

2. Precise Phase Angle Measurements-Preliminary Adjustments

1. Set the frequency selector to the proper band for the frequency to be measured.

2. Switch Function Selector to a phase sensitive position.

3. Connect the reference voltage to the REF input terminals of the instrument. With the reference HI-LO switch and reference level control, adjust the reference input to give an ON scale reading on the reference level meter. (No particular setting is required, as the instrument will operate over a wide range of reference level. As long as an ON scale reading is maintained, the instrument will remain within calibration tolerances.

4. Depress "EQUAL" switch and note if there is any change in reference level meter from that observed in Step 3.

5. With "EQUAL CONTROL" knob, re-adjust reference meter to original reading. Adjust this control until there is no change in reference level when "EQUAL" switch is depressed or released.

6. Depress "ZERO" switch and, using the ZERO adjust knob, adjust Phase Angle Voltmeter to read exactly zero. Release ZERO switch and proceed with measurements.

NOTE: The above steps have aligned the Phase Angle Voltmeter for

accurate measurements at a particular set frequency. Maximum accuracy may be had at any frequency in the spectrum of 10~ to 100KC by following this procedure. The "EQUAL" procedure outlined in Steps 4 through 5 need only be done if the phase dial is set to other than "0°" or "90°." (See Theory of Operation, Paragraph 2-D)

3. Sweep Frequency Measurements

1. If it is desired to sweep a band of frequencies or if the frequency of operation is changing from time to time (within the half-decade covered by the frequency switch), it will be necessary to follow the adjustment procedure outlined in Section IV, Paragraph 2. This adjustment procedure will align one frequency in the half-decade being covered to "Set" frequency accuracy. Measurements throughout this half-decade may now be taken without further adjustments to an accuracy of ±2°.
2. Whenever the frequency switch is switched to a new half-decade step, it is necessary to follow the procedure of Section IV, Paragraph 2 for one frequency within the half-decade.
3. For convenience of reference level tracking and to assure sweep frequency accuracy over the whole half-decade step, the frequency used for initial adjustment should be near the center of the band. Because of the parabolic shaped phase curve of the phase networks, this will be the Geometric Mean. For the 10 to 31 base bands, this center is 17.8; for the 31 to 100 base bands it is 56 (i.e. in the 316 to 1,000~ band, the center frequency will be 560~).

4. Phase Angle Measurements-With Calibrated Phase Shifter

1. Adjust Reference Channel as described in Section IV, Paragraph 2 or IV, Paragraph 3.
2. Switch the Function Selector to a suitable Phase Angle Voltmeter position and turn the degrees dial to read a near maximum.
3. Switch the Function Selector 90°. Turn the degrees dial until the meter reads zero. Switch the Function Selector to a position (0°, 90°, 180°, or 270°) which gives a meter deflection to the right. The phase angle is then the sum of the function selector angle plus

the dial angle. This rule eliminates the possibility of ambiguity.

NOTE: IT IS VERY IMPORTANT TO USE THE EQUAL CONTROL WHEN USING THE CALIBRATED PHASE DIAL.

5. Phase Angle Voltmeter Measuring In-Phase & Quadrature Components

Accurate measurements of phase angle can also be made using the E cosine ϕ or E sine ϕ characteristic. Voltage measuremets are made of the in-phase or quadrature component and of the fundamental signal (STD VTVM position). The quotient will then be the cosine or sine of the unknown phase angle. Trigonometric tables, slide rule, or graphs included in the appended application notes are suitable for converting to degrees. The accuracy achievable using this technique depends upon the procedure, and for that reason it is suggested the application notes be reviewed before using this method.

1. With reference channel adjusted as described in Section IV, Paragraph 3, place Function Selector in 0° position. Set the phase dial at 0°.
2. The meter now reads the in-phase component of a signal. This is also E cosine ϕ where ϕ is the angle between the reference and signal.
3. Switch the Function Selector to 90°. The meter now reads the quadrature component or E sine ϕ. In general, one of these components is usually much smaller than the other and for greater accuracy it is convenient to change the range of the instrument. This can be done until the overload lamp lights, thereby warning of an impending overload condition. This light indicates that the total signal exceeds 10 times the full scale value.

6. Filter Operation

A. General

Due to the inherent errors in making phase measurements on signals rich in harmonics, it is usually necessary to use harmonic filters to achieve the ultimate accuracy of this measurement. It is also sometimes desirable to make non-phase sensitive measurements on input signals

after removing noise and harmonic components. Therefore, it is possible to switch filters into both channels using the Filter "In-Out" switch while making both phase sensitive and non-phase sensitive measurements.

The filters used are plug-in, low pass types with a characteristic described by Figure 4.1. The filters are operated in a restricted portion of the pass band in order to maintain, over this band, the amplitude gradient within the instrument specification and to restrict the phase variation. It will then be possible (at any frequency within the band) to make adjustments in the Filter "Out" position and switch to the Filter "In" position without having to make any further adjustments. Usable bands limits were determined as follows:

1. Upper frequency limit is determined by the amplitude vs frequency characteristic.
   Lower frequency limit is determined by the amount of the third harmonic of this frequency.
2. Bands designated $f_a(.45f_o - .6f_o)$ will have an amplitude variation of 1% over the frequency band and 30 db rejection of $.45f_o$. (f_o is the frequency where the amplitude is down 6 db* from the low frequency amplitude. See Fig 4.1).
3. Bands designated by $f_p(.4f_o - .65f_o)$ will have an amplitude variation of 2% over the frequency band and 20 db* rejection of the third harmonic of the lowest frequency.
4. f_m designates the geometric mean frequency of the usable band. Table I describes all filters available and their usable bands.

*NOTE: When making phase sensitive measurements, the detector circuit inherently has high second harmonic rejection (approximately 55 db) and 10 db additional rejection of the third harmonic.

This additional harmonic rejection is, therefore, added to the filter rejection when operating in any phase sensitive mode.

It is possible to extend the range of any filter if additional attenuation is desired. If this is done, the filter adjustments described below must be made at each frequency used, and the usable band width around this frequency is severely limited. It is not recommended that a frequency of $0.85f_o$ be exceeded.

B. Filter Adjustments

Pull out meter drawer and insert desired filters into octal sockets.

1. Amplitude Adjustment

a. Put in any convenient level of input signal at the f_m frequency of the filter.

b. Place Function Switch in VTVM position.

c. Turn Filter in-out Switch to OUT position.

d. Turn Range Switch to range corresponding to ON scale reading with signal input available.

e. Observe reading on meter. This should be as close to full scale as possible.

f. Switch to Filter-in position and adjust R 105 Filter Level Adjustment for the identical reading observed in Step d.

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TABLE 1

PART NO.	f_m	f_o	f_a (.45 to .6) f_o		f_p (.4 to .65) f_o	
200613-1	39.0	75	Not Used in VM301		Not Used in VM301	
200613-2	52.0	100	45	60	40	65
200613-3	62.5	120	54	72	48	78 *
200613-4	83.2	160	72	96	64	104
200613-5	111	213	95.8	127	85.2	138
200613-6	146	282	127	169	113	183
200613-7	195	376	169	223	150	244
200613-8	260	500	222	300	200	322
200613-9	346	665	299	399	266	432 *
200613-10	416	800	360	480	320	520
200613-11	520	1.00KC	450	600	400	650 *
200613-12	675	1.30KC	585	780	520	845
200613-13	785	1.51KC	680	905	605	972 *
200613-14	1.09KC	1.92KC	865	1150	765	1240
200613-15	1.23KC	2.25KC	1015	1350	900	1460 *
200613-16	1.56KC	3.0KC	1350	1800	1200	1950
200613-17	2.11KC	4.06KC	1800	2440	1600	2600
200613-18	2.86KC	5.5KC	2440	3300	2200	3580
200613-19	3.18KC	7.34KC	3300	4400	2930	4760
200613-20	4.84KC	9.5KC	4125	5500	3660	5850 *
200613-21	5.35KC	10.3KC	4640	6200	4125	6700
200613-22	7.15KC	13.75KC	6200	8250	5500	8850
200613-23	9.53KC	18.33KC	8250	11KC	7350	11915

* This indicates filters which may be omitted when using f_p accuracy and still have complete frequency coverage.

SECTION V

THEORY OF OPERATION

The Functional Schematic of Fig. 5.1 will serve to illustrate the principle of operation of the Phase Angle Voltmeter in its entirety. Note that detail schematics showing all components are also included as Figures 5.2 through 5.10.

1. Signal Channel

A. Input Attentuator & Preamplifier.

The 1,000:1 resistive divider feeds into the grid of cathode follower (1/2 V101). A six step voltage divider forms the cathode resistor for this tube. Connection for both these attenuators is accomplished by the range switch (S1). For inputs from .001 to .3 Volts, the signal is applied directly to the grid of V101. For input of 1 to 300V the signal is attenuated by 1,000:1. The six step divider switch section is arranged so that its rotor has two moving arms located 180° apart. As the range switch is rotated through its full range of rotary travel, contact is made twice with each of the six taps; once for the six low ranges, once for the six high ranges. On the six high ranges, the input signal is divided down before it is applied to the six step divider, each tap on the divider serves two ranges, giving a total of twelve ranges. Connections on both attenuators are arranged so that the output of the six step divider is maintained at approximately .001 volts which corresponds to full scale voltage for each range.

The RC networks on the six step divider serve to reduce switching transients and maintain proper ratios at all frequencies. The variable capacitor (5-25mmfd) and the 1,000:1 divider compensates for stray capacity and maintains the division ratio.

When no filters are employed, the cathode follower (1/2 V101) output is applied directly to the input of the main signal amplifier.

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When filters are used, output of the cathode follower is applied by means of the filter switch to the second 6AB4 (V102). This stage operates as a low gain amplifier to supply the proper driving impedance for the filter, and to compensate for filter insertion loss. Recalibration of the voltmeter when changing filters is accomplished by two potentiometers (R105- for amplitude) and (R318 - for phase). Both are located in the filter slide draw. (For proper adjustment procedure for this calibration, see Filters - Section IV, Par. 6).

B. Signal Amplifier

This four tube amplifier provides high gain over a wide frequency range. The output of the amplifier drives the phase sensitive rectifier and an indicator circuit which is biased by means of R-1201 and R-1003 in order to indicate overload conditions.

The amplifier yields a net gain of 55 to 60 db over a wide frequency range. A high degree of stability is obtained by use of negative feedback and cathod degradation at low frequency. In addition, the frequency response and stability is intensified by the use of compensating networks in the plate and screen circuit of each stage.

The pentode section of the dual tube (V204) drives the rectifier and meter circuit. The amplifier feedback is returned from the plate of this tube through the meter rectified circuit to the cathode of the first amplifier tube (201). The overall gain of the amplifier is adjusted by means of the calibration potentiometer located on the back panel of the voltmeter. High frequency response compensation of the feedback loop is accomplished by adjustment of (C213).

The second half of V204 is used to operate the overload circuit. The point at which the light illuminates

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on the indicator is adjusted by means of potentiometer R1003, mounted on the chassis to the rear of the Phase Pot Housing.

2. Reference Channel

A. Input Attentuator & Preamplifier

The 3:1 resistive divider feeds into the grid of cathode follower 1/2 V301. A frequency compensated potentiometer forms the cathode resistor for the tube. The combination of these two attenuators allows the reference channel to be adjusted over the range of .15 to 130V input.

When no filters are employed, the signal is applied directly to the grid of the first reference amplifier tube, V301.

When a reference filter is used, the output of the cathode follower is applied by means of the filter switch to the second half of V301. This stage operates as a low gain amplifier to supply the proper driving impedance for the filter and to allow phase adjustment between the signal and reference channel filters. This adjustment is accomplished by R318, located on the left side of the filter draw. For proper procedure of this adjustment, see Filter Section IV, Par. 6.

B. Reference Amplifier

This three tube amplifier supplies the necessary gain and low impedance output required for driving the phase shifting networks. Frequency response and phase shift characteristics are carefully controlled by compensating networks in the plate and cathode circuits. Negative feedback to the cathode of the input tube is passed through networks selected by the frequency switch for proper frequency shaping. The second half of the input tube, operating as a phase splitter, feeds two cascaded, push-pull stages.

The output stage, consisting of the two triodes, operates similar to a cathode follower with transformer coupled output. In order to cover the complete frequency band, use one transformer for the low band and a different transformer for the high band. The proper units is selected by the frequency switch.

C. Phase Networks

A unique, patented, passive phase network design is used to establish +90° and -90° voltages. The 0° and 180° voltages which are derived from the center tapped secondary of the reference output amplifier also represent the source for the phase networks. The four outputs resulting from this circuit configuration (0°, +90°, -90°, and 180°) are applied to a resistive bridge, one leg of which is the calibrated variable phase potentiometer. By switching the potentiometer from one leg of the divider to another by means of the function switch, any one of the four quadrants of 90° each appear across the potentiometer.

D. Zero and Equal Controls

An integral part of the phase networks, these controls perform trimming adjustments to compensate for the frequency and amplitude characteristic of the phase network filters.

E. Reference Drive Amplifier

This amplifier receives the signal from the calibrated phase potentiometer and drives the reference side of the phase sensitive detector when the function switch is in any of the phase sensitive position. This amplifier is a wide band, highly stabilized, phase corrected amplifier.

3. Phase Sensitive Rectifier

The Phase Sensitive Rectifier circuit is a gated, bridge

SECTION VI

MAINTENANCE

The following section contains instructions for the general maintenance of the Phase Angle Voltmeter. Detailed alignment procedures are described in Section VII. It is recommended that alignment procedures be followed only if proper test equipment and sufficiently skilled personnel are available to perform the work.

1. Cover Removal

A. Top and bottom covers are held in place by twelve screws each. Remove either set of twelve screws to allow removal of the corresponding top or bottom cover. (When replacing covers, be sure the open screen cover is placed on top of the voltmeter.)

B. To remove the back cover, remove the three rear screws in both the top and bottom covers, the four corner screws in the back cover, and one screw in the center of the back cover.

2. Tube Replacement

CAUTION: DO NOT REMOVE TUBES FROM THE VOLTMETER BEFORE REMOVING POWER.

A. With the exception of Circuit V201, no circuit in the VM301 is critical to tube replacement. However, for maximum accuracy the calibrations (as described in Section VII) should be checked following tube changing.

B. When replacing V201, it will be necessary to monitor the plate voltage of V202. This is at the top of R212 (5.6K, 1/2W Resistor) located directly under the V202 tube socket on the component board. A V201 (6BH6) Tube should be chosen so that this voltage will be 150 ± 5 volts to ground.

C. Before changing the settings of any of the internal adjustments, check the tubes.

3. Replacement of Parts

A. To remove and replace any of the tubes, it is

demodulator. Its operation can be likened to that of a set of commutating switches. The reference signal alternately connects one side of the meter to ground through R242 and R220 and then the other end on the reverse cycle of the reference. The signal is, therefore, synchronously rectified through the meter movement. If the reference and signal are in phase, the average value will be a maximum and the meter will read a maximum. If the signals are 90° apart the average will be zero and no reading will result. The equation governing this is:

$$I_{Meter\ (avg)} = K E \cos \phi$$

Where K = Proportionality constant
E = RMS of Signal
ϕ = Angle between Signal and Reference.

Demodulator saturation effects will limit this characteristic equation to the designed levels for the instrument. Under special conditions, such as are described in the appended Application Notes, the reference level is increased to improve accuracy for high signal levels. Measurements at the quadrature null point ($\phi = 90°$) are unaffected by saturation.

The response of the phase sensitive detector is limited to signals at the reference frequency as well as to odd order harmonics. All other frequencies are rejected, except for signal very near the reference frequency. Here, the meter movement will oscillate between plus and minus maximums at a rate equivalent to the difference between the signal frequency and the reference frequency. Response for this type detector to odd order harmonics will never be greater than the fundamental response multiplied by a factor of 1/n, where "n" is the order of the harmonic. In fact, it will usually be less and dependent upon the phase angle. Where a signal channel filter is used there is, of course, essentially no response to harmonics in the signals.

The effect of reference harmonics is much less important than that of signal harmonics because the harmonic content

can never do more than shift the point at which the diodes start to conduct. In other words, there is an equivalent error in degrees which results from harmonics in the reference channel. For measurements using the phase shifter, the error can be removed by trimming. For measurements using the E cosine Φ characteristic, the resultant error is small because the meter reading is a function of current integrated over an entire cycle and the small error produced by distortion has a correspondingly small effect on the total current.

necessary to remove the top and back covers of the instrument.

B. Most trouble-shooting can be done by removing the top, bottom and back covers. If it is desirable to inspect the boards mounted on the inside of the rear board panel, or the terminal boards located under the power transformer, the inside rear panel may be dropped on pivots to a horizontal position. To accomplish this, remove the two screws on either side of the inside rear panel above the pivot mechanism.

C. Although any component may easily be changed with the boards in place, should it be desirable to remove a board, remove the proper screws from the front of the board. Long-nosed pliers may be used to remove the taper pins from the board terminals - a slight twist and pull is sufficient, however. A proper taper pin insertion tool should be used to replace the pins. Such a tool is the AMP (Air Marine Products) CERTI-LOK insertion tool No. 380306-3.

D. Panel Lights in the meter box are removed from the rear of the meter by pulling the meter slide draw forward. Panel Lights for the phase dial are clip-mounted on the phase dial potentiometer housing.

E. Several resistors in the voltmeter are precision components. If these resistors require replacement, use the same value and type as the original. If different values are used or components are moved, calibration or frequency response may be affected and re-adjustment may be required. Be careful to replace components as closely as possible in the same position the original components occupied. Pay careful attention to wiring and do not reroute or move any of the wires.

F. Semiconductor transistors and diodes are used throughout the instrument in the amplifiers, power supply and meter circuit. If replacement is necessary, standard semiconductor practices are necessary. If any of the diodes in the meter circuits CR 204, CR 205, CR 206, CR 207 are replaced, the voltmeter calibration, frequency and phase calibration should be checked.

SECTION VII

CHECKOUT & ALIGNMENT PROCEDURE

TEST EQUIPMENT REQUIRED:

1. AC VTVM - Ballantine 300H or Equivalent
2. Audio Generator - Hewlett Packard 200 CD or 650A
3. Phase Standard - Capable of generating;
   a. $90^{\circ} \pm .05^{\circ}$ from 10CPS to 100KC
   b. $45^{\circ} \pm .05^{\circ}$ at 1KC
4. Attenuator - Kay Electric 31-0
5. Power Amplifier - Khronhite DC 10A
6. Multitester - Tripplett 630 or equal

1. Initial Ground Check

Check for stray ground path. Should read OPEN (no reading on X100,00 Range) from signal ground (black terminal post) to chassis (metal terminal post), Should also read OPEN from Pin 18 power supply board to chassis.

2. Initial Power Supply Voltage Check

A. Short reference and signal input terminals. Short signal ground post and chassis (metal post).

B. Third prong on power plug should be connected to house ground on metal binding post.

C. Apply power to Phase Angle Voltmeter. Observe filiments, pilot lights. Make sure that neon light on power supply ignites within a minute.

D. Measure and, if necessary, adjust the following (on power supply board):

PIN	DC VOLTS	AC VOLTS	ADJUST
10	-79 to -81	Approx. 200uv	R908 (27K Nom.)
11	+255 to +265	" 1mv	R938 (1.3K Nom.)
12	+175 to +200	High 8-10 volts	No Adj.
15	+260 to +270	Approx. 90mv	No Adj.
7	-12 to -12.6	" 30mv	R930 (39K Nom.)
8	Ground (Tied to Signal Ground in Signal Amp.)		

NOTE: If there is excessive ripple on the -80 (Pin 10) and +260A (Pin 11), R937 (-80) and R912 (260A) may be adjusted to minimize this voltage.

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3. Voltage Range Adjustment (Low Range)

A. Connect Signal Generator to monitor AC VTVM and input of the Attenuator.
B. Connect output of Attenuator to input of VM-301.
C. Switch Function Switch to VTVM.
" Filter Switch to OUT.
" Frequency Switch (not used).
D. Adjust Signal Generator to 1 KC and 1 volt output.
E. Set Attenuator to 1 millivolt output.
F. Set Range Switch to 1 millivolt and adjust calibrate potentiometer R242 on back panel for exactly 1 millivolt on Voltmeter.
G. In steps corresponding to the Range Switch steps, check all ranges to .3 volts.
H. Repeat Steps A through G at 10~, 20~, 500~, 10KC, 50KC, and 100KC.

NOTE: All readings should be at least:
±2% from 20~ to 50KC
±3% from 10~ to 100KC

4. Reference Pre-Amp Adjustment (This should be done any time Tube V-301 is changed).

Adjust D.C. voltage on Pin 16 of D-500086 (Reference Pre-Amp) to equal ZERO with R309.

5. ZERO EQUAL Control Operations

Before continuing further with the tests, review the following points:

A. Whenever Phase Sensitive measurements are being made, it is necessary to zero and sometimes equal the Model VM-301 each time the frequency, any major input, or function, is changed. In the following tests this will be referred to as "EQUAL & ZERO."
B. EQUAL: This is done by adjusting Reference Signal Level to obtain an ON scale reading on the Reference Level Meter. Depress the EQUAL Switch and adjust the equal control so that there is no change in reference level when the EQUAL Switch is normal or depressed. This

need only be done if the Phase Dial is not in the 0° or 90° positions.

C. ZERO: Depress the ZERO Switch and adjust the zero control to read "ZERO" on the voltmeter.

6. ZERO Switch Adjustment

A. Connect Signal Generator output to reference and signal terminals.
B. Set Function Switch to "0°."
C. " Filter Switch to "OUT."
D. " Range Switch to .3 volts.
E. " Frequency Switch to KC and 3.16 to 10KC.
F. " Signal Generator to 5KC and adjust output (no attenuation) to .3 volts. Set Range Switch to .1 volts.
G. Set Reference Level Switch to "LO" and adjust Reference Level Potentiometer to give approximately half-scale reading on Reference Meter.
H. Zero.
I. Switch Function Switch to 90°. Meter will read approximately ZERO.
J. Adjusting Zero Potentiometer with ZERO Switch released and adjusting C308 with ZERO Switch depressed, the meter should be made to read "0" in both positions of the ZERO Switch. (See Figure 7.2).

7. Reference HI-LO Switch

A. Set Frequency Switch to KC and 1-3.16 position.
B. " Reference Level Potentiometer to full clockwise.
C. " Function Selector to 0° position.
D. " Range Switch to 3 millivolt range.
E. " Signal Generator to 1.6KC. Adjust output to give approximately half-scale reading on Reference Meter.
F. Adjust Attenuator to give full scale reading on voltmeter. Switch to 1 millivolt range.
G. Switch Function Switch to 90° without depressing ZERO Switch. Adjust zero control to make the voltmeter read exactly ZERO.
H. Switch HI-LO Switch to "HI."
I. Re-adjust Signal Generator to give half-scale reading on Reference Level Meter.

J. Switch to 3 millivolt range. Adjust Attenuator to give full scale reading. Switch to 1 millivolt.
K. Adjust #C303 for ZERO meter reading. (Located on reference pre-amp board near .1 mfd. input cap.).

8. High Signal Range Adjustment

A. Set Frequency Switch to KC and 1 through 3.16.
B. " Range Switch to 3 volts.
C. " Function Switch to 0°.
D. " Reference Switch to LO.
E. Adjust Signal Generator to 1.6KC and full scale output reading on meter.
F. Adjust Reference Level Potentiometer to give approximately half-scale reading on Reference Meter.
G. Adjust Attenuator to give .3 millivolt output. Switch Range Switch to 1 millivolt position.
H. Switch Function Switch to 90° position.
I. Zero.
J. Switch Range Switch to 1 volt position and remove attenuation from signal channel.
K. Adjust C1301 mounted on Range Switch to bring voltmeter to ZERO.
L. Check 90° position all voltage ranges.

9. Overload Adjustment

A. Set Function Switch to "0°."
B. " Filter Switch to "OUT" position.
C. " Range Switch to 1 millivolt.
D. " Frequency Switch to 1 to 3.16KC range.
E. Adjust Generator, Attenuator Box, and Range Switch to give 1 millivolt full scale reading on voltmeter at 1KC.
F. Increase input signal for 10 times overload.
G. Adjust overload potentiometer (R1003) so that overload light just starts to blink.
H. Compare input voltage causing light to blink vs. voltage drop causing the light to extinguish. (Both should occur at the same point at all frequencies, 10~, 500~, 10KC, 50KC, 100KC). It may be necessary to adjust R229 of Signal Amp Board for proper overload indication at 10~.

10. Phase Network Alignment

A. Connect output of Signal Generator to both input and reference terminals.
B. Set Range Switch to a position so that a 10 times overload is achieved (e.g. If input is 30mv, use 3 mv scale.).
C. Set Function Switch to 90°.
D. " Reference Level to give half-scale reading on Reference Level Meter.
Set Frequency Switch as required.
" Phase Dial on ZERO.
E. Rotate zero control until meter reads a null.
F. Connect output of Phase Standard to signal input terminals of VM-301. (NOTE: If output of Phase Standard is noisy and voltage levels are convenient, it is better to put this noisy input into the reference channel.)
G. Set Range Switch to a position so that a 10 times overload is achieved. (e.g. If input is 30mv use 3 mv scale).
H. Set Function Switch to "0°."
" Reference Level to give half-scale reading on Reference Level Meter. Set Frequency Switch as required.
I. Meter should read ZERO. Trim the necessary capacitor to make it so (see Table I).
J. After trimming, it should be possible to switch 90° in and out of reference channel and compensate exactly with the 0° to 90° Function Switch.

SHIFTER	301	METER
90°	0°	0
0°	90°	0

K. Trim four bundles at the following frequencies:

FREQ.	BAND	BUNDLE	TERMINALS	APPROX. TRIM
5.62~	31.6 to 100~	2	1 & 10	.0013
178~	100 to 316~	3	"	.0004
562~	316 to 1000~	4	"	.00013
1.78~	1KC to 3.16KC	1	"	.004

L. Checks should be made, at the end and mid-frequencies for each band (see Phase Standard Chart for bands and settings).

11. Phase Potentiometer Trimming

A. Repeat Steps A through E of previous Section 10 for 1KC operation on the CPS range.
B. Adjust equal control.
C. Connect output.
D. Set Function Switch VM-301 to 0°.
" Frequency Switch to ~ and 316 to 1000.
" Filter Switch to OUT.
E. Equal.
F. Zero.
G. Switch Function Switch to 90° position.
H. Turn Phase Dial to 45°.
I. Switch Phase Standard to 45°.
J. Adjust C608 until voltmeter reads ZERO when the switch is depressed and released. After adjustment, it should be possible to switch in or out 45° with the Phase Shifter and exactly compensate for this shift with the Phase Dial ($45^{\circ} - 0^{\circ}$) with no change in the ZERO reading of the voltmeter.

CAUTION

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration or setting up of instrument.

APPLICATION NOTES

FOR

SERIES 200

PHASE ANGLE VOLTMETERS

The North Atlantic Industries Series 200 Phase Angle Voltmeter is a truly unique, multifunctional instrument which will function as a sensitive voltmeter, a phase angle meter, a meter measuring in-phase signals (E cos θ), and quadrature signals (E sin θ), a phase sensitive null indicator, an impedance meter and a power factor meter.

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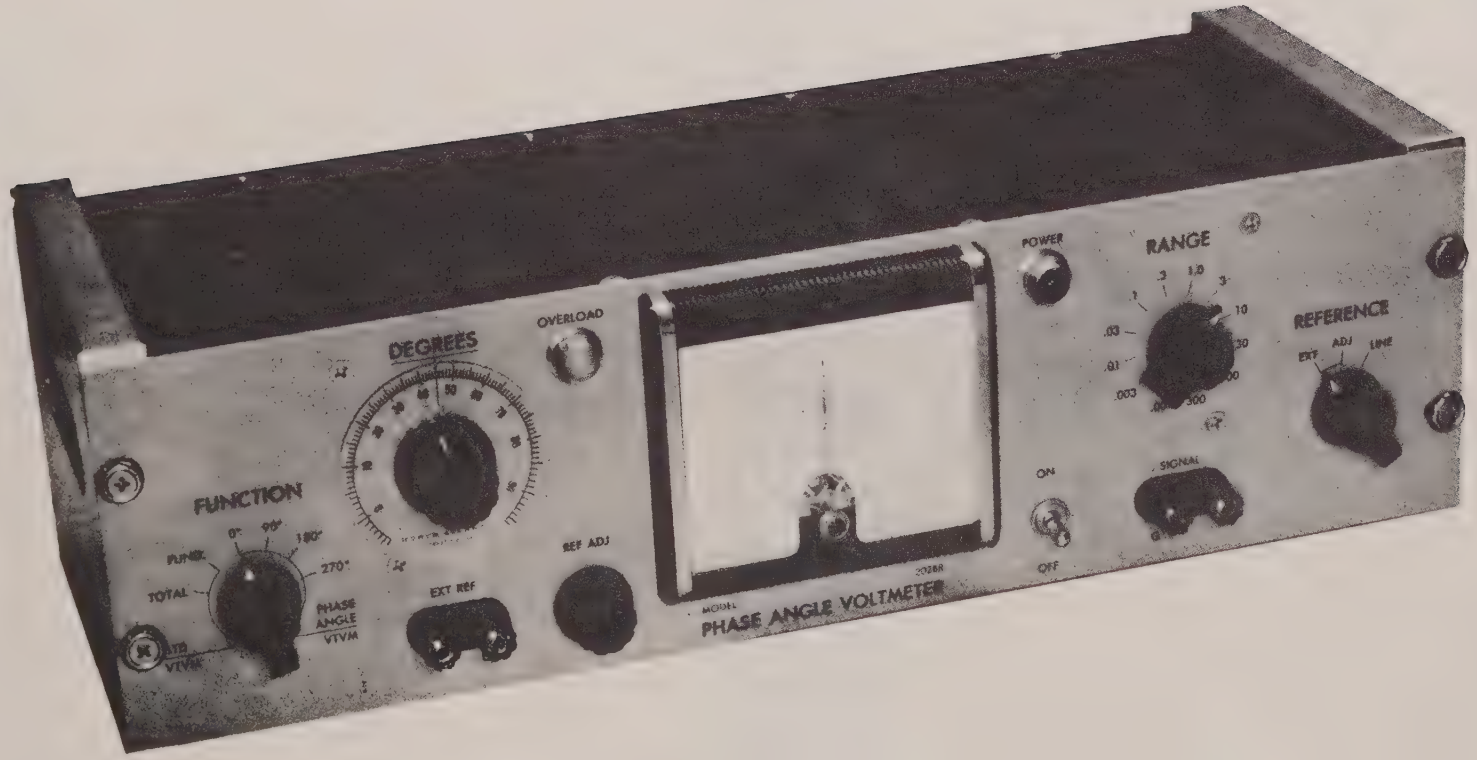

PHASE ANGLE VOLTMETER

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I-INTRODUCTION

The following notes will acquaint the user of the 200 Series Phase Angle Voltmeter with the many ways in which these versatile instruments can be used.

By virtue of the instruments ability to measure the two basic characteristics of any signal, namely magnitude and phase angle, measurements are now possible which previously either required extensive associated equipment or could not be made at all.

The principle of operation is illustrated in Figure 1.

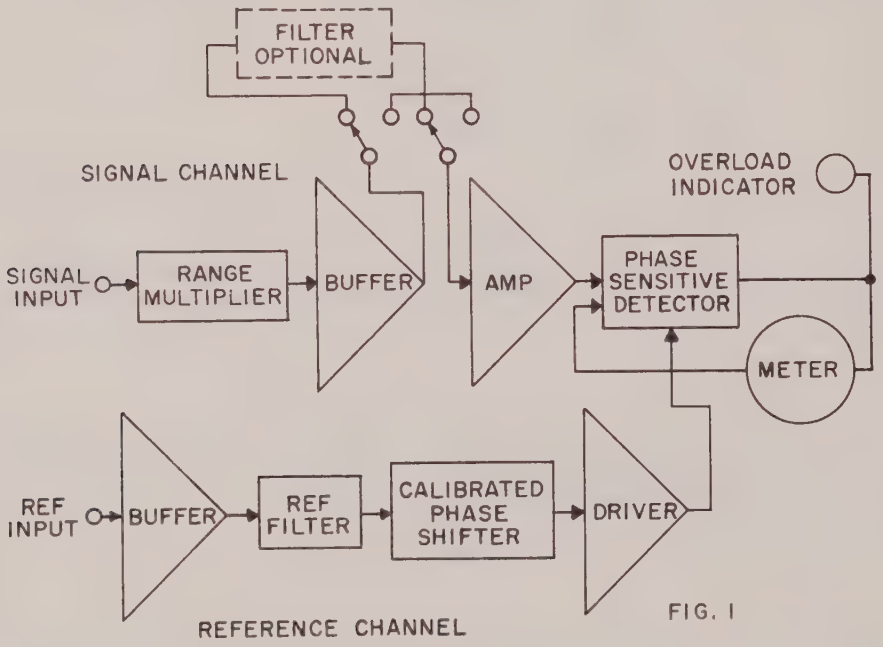


FIG. 1

An input signal is first attenuated by the range multiplier. The high gain amplifier drives a phase sensitive detector which in turn drives the indicating meter. The meter output is recombined to form an a.c. signal which is fed back to the amplifier input thus making the instrument independent of diode characteristics and tube ageing. A reference signal is also amplified and its phase angle shifted by the calibrated phase shifter. This signal driving the phase sensitive detector results in the phase angle characteristics shown in Figures 5 and 6.

The sections to follow describe the many ways in which this instrument is being used. Block diagrams illustrate typical measuring set ups.

II-GENERAL NOTES ON GROUNDING TECHNIQUES

Successful measurement with any high input impedance voltmeter is dependent upon the elimination of all unwanted or extraneous signals from the measurement circuit.

The most common sources for extraneous signals are the following:

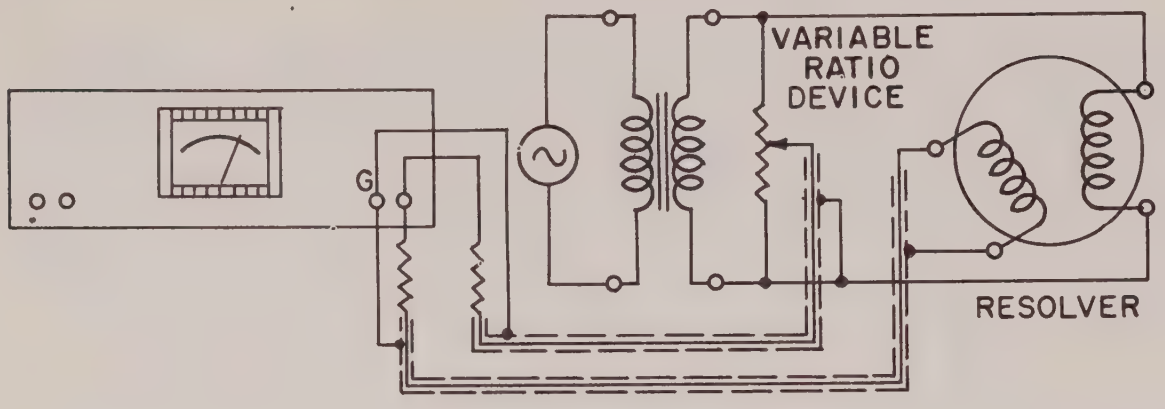
(a) Internal noise
(b) Electrostatic pickup
(c) Inductive pickup
(d) Common Ground Runs

Internal noise has been minimized by design and is equivalent to less than 5 microvolts for a high impedance circuit (1.0 megohm).

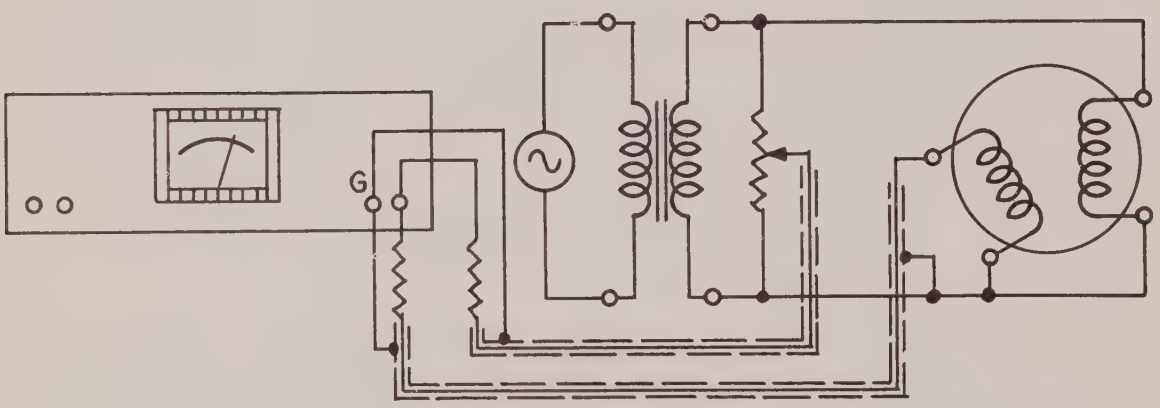
Electrostatic pickup, frequently a problem in high impedance circuits, is easily eliminated by shielded cable or twisting leads, one of which is at ground potential. Care must be taken however to avoid loading the signal source by the by the cable capacitance.

Inductive pickup is generally less often encountered than electrostatic pick-up and possibly for that reason methods for minimizing it are not frequently employed. Both twisted and shielded leads are effective in reducing this form of pickup because they minimize the effective area through which extraneous electromagnetic flux can pass. This is true in the case of a shielded lead, only if the shield, for example, is the return circuit for the signal.

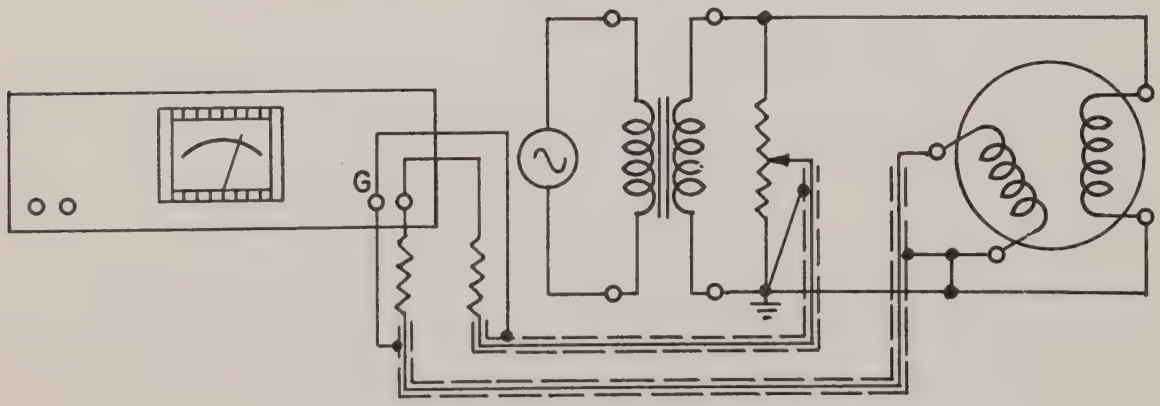
Inductive pickup in ground leads can and does occur with multiple point grounding systems. The effect of these ground loops frequently can be reduced by bundling cables together, again so as to minimize loop areas. A better method is to eliminate the ground loops altogether especially those in the signal system or that portion of a circuit where a measurement is being made. Fig. 2 shows several workable methods for using the voltmeter as a phase sensitive null detector when making transformation measurements. All methods can be made to work by minimizing stray fields and bundling cables together. However, Figure 2A is the most advantageous arrangement and is not at all critical to lead runs. Figures 2B and 2C both have loops which can be potential trouble spots. Note also that grounds other than those shown in Figure 2 can exist due to chassis contact, line cord ground and reference grounds. All must be considered when setting up the measuring system.



(a)—GOOD, NO LOOPS



(b)—ONE LOOP, PICK-UP POSSIBLE



(c)—POOR—ONE SIGNAL LOOP AND ONE GROUND LOOP

FIG. 2—RATIOMETER WITH SERIES SUMMING

Common Ground Runs are sources of extraneous signals by virtue of voltage drops in the voltmeter input which arise from ground current other than the signal ground current. Figure 3 is a sketch of a typical arrangement wherein the power ground lead is in part that of the shield on the signal input. A portion of the load current as well as power supply leakage current to ground go through the voltmeter input cable. The voltage drop in the length of common ground is measured in addition to the signal.

Figure 3 also illustrates the internal grounding arrangement. The fact that there are four places in which a ground can be made could mean that isolation transformers are required somewhere in the measuring circuit.

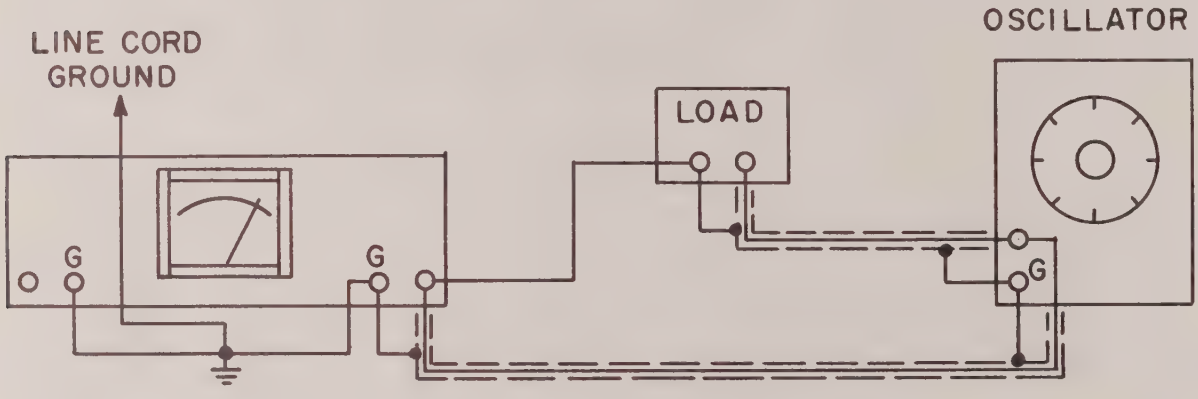


FIG. 3

III-PHASE CHARACTERISTIC

The response of the Phase Angle Voltmeter to the fundamental frequency is given by:

(1) $E_{meter} = E_{rms} \times \cos \theta$

where E_{meter} = voltage read on the meter

E_{rms} = rms value of the input sine wave

θ = angle between the reference and signal input (phase shifter at zero degrees)

Response to even order harmonics is theoretically zero, while odd harmonic response varies inversely with the order of the harmonic.

For example, for the 3rd harmonic equation (1) becomes:

$$E_{meter} = \frac{E_{rms\ (3rd\ harmonic)} \times \cos \theta'}{3}$$

where θ' is the phase angle of the 3rd harmonic with respect to the reference.

Actually response to harmonics departs from equation (2) for a number of reasons. Since calibration of the instrument is at the fundamental frequency, measurements at frequencies other than the fundamental frequency will be somewhat in error.

For instruments having selective filters in the signal and reference channels, harmonic response will in all cases be more than 55 db down. Table I shows typical measured responses. The values shown with filters actually are the sum of the column I data and the filter characteristic.

TABLE I

	RESPONSE SIGNAL	
	No Signal Filter	With Signal Filter
FUND (400 cps)	0 db	0 db
2nd Har	-55 db	> -55 db
3rd Har	-9.5 db	> -55 db
4th Har	-55 db	> -55 db
5th Har	-14 db	> -55 db

Measurements of phase angle using equation (1) are easily accomplished with good accuracy using the set-up shown in Figure 4. The actual phase characteristic used in the measurement is E sin θ for purpose of convenience. The procedure is to adjust accurately the $\theta = 90$ deg. and the $\theta = 0$ deg. point. Measurement then will be a voltage which can be directly translated into degrees using the curves of Figures 5 and 6.

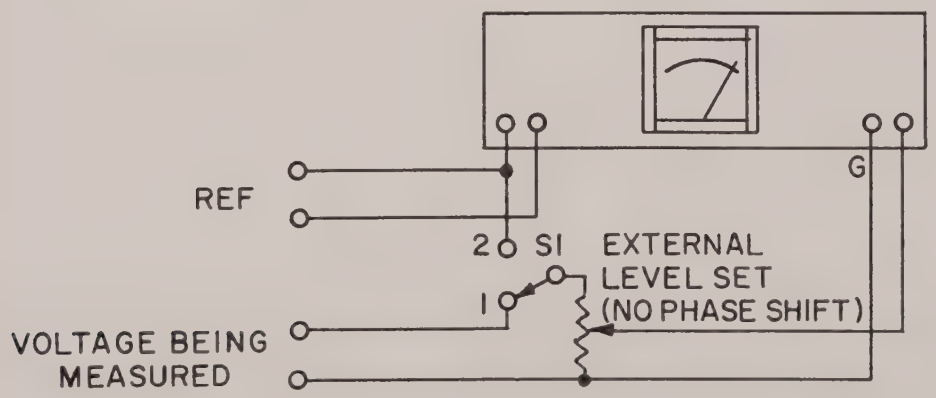


FIG. 4

The step-by-step procedure is:

1. Set reference level to red line value.

2. With meter in "STD VTVM" position and external switch S1 in position 1, select a convenient range and adjust the signal level for full scale deflection. This will insure on-scale readings. (Note: Any external level set should be sufficiently low in resistance so as not to introduce phase shift error.

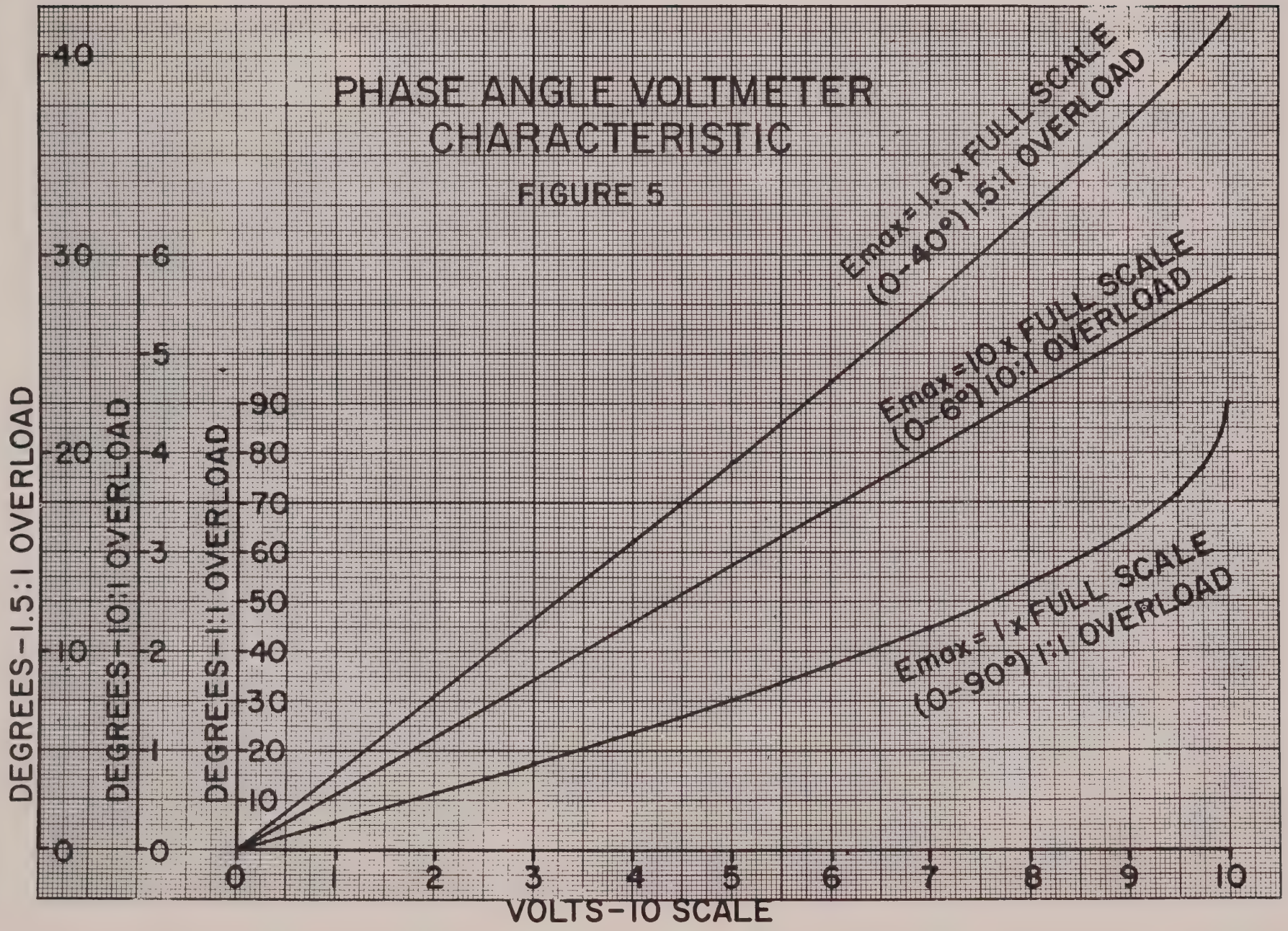
3. Next switch the reference into the signal channel by switching S1 to position 2 and adjust using the same external level control for full scale deflection. Switch the instrument to the "PHASE ANGLE VTVM" function and adjust the phase shift dial for zero meter reading. This establishes the $\theta = 0$ deg. point or quadrature null point. NOTE: FOR MAXIMUM ACCURACY THIS POINT SHOULD BE RESET WHENEVER THE SCALE IS CHANGED.

4. Return the switch S1 to the signal input and readjust the full scale level with the instrument set as "STD VTVM". This establishes the $\theta = 90$ deg. point. (E maximum).

5. Switch back to the "PHASE ANGLE VTVM" position used in (3) above and read the meter. Enter the curves of Figure 5 or 6 to read degrees.

Any full scale range in degrees can be used even down to $-6^{\circ}-0-+6^{\circ}$ depending upon the full scale limits. For example, if the full scale 90 degree point is set on the 1.0 volt scale and the zero point on the 3.0 volt scale, then the 3.0 volt scale will cover a range of from -17.4 deg.-0- +17.4 deg. Table II summarizes typical set-ups and Figures 5 and 6 show curves which can easily be used to convert voltage measurements to degrees. These curves are actually arcsin functions. The angle can also be derived by direct computation from the voltage readings.

Errors in using this type of measurement will be a function of the scale used and the angle. In addition, for large ratios of maximum voltage to full scale values being used, saturation for a portion of each cycle can occur and will result in a small scale error. Obviously this condition is a function of reference level and for that reason a level of twice the red line value is recommended when using this techique.


PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 5
Emax = 1.5 x FULL SCALE
(0-40°) 1.5:1 OVERLOAD
Emax = 10 x FULL SCALE
(0-6°) 10:1 OVERLOAD
Emax = 1 x FULL SCALE
(0-90°) 1:1 OVERLOAD
DEGREES-1.5:1 OVERLOAD
DEGREES-10:1 OVERLOAD
DEGREES-1:1 OVERLOAD
VOLTS-10 SCALE
0
10
20
30
40
1
2
3
4
5
6
7
8
9
10
60
50
70
80
90

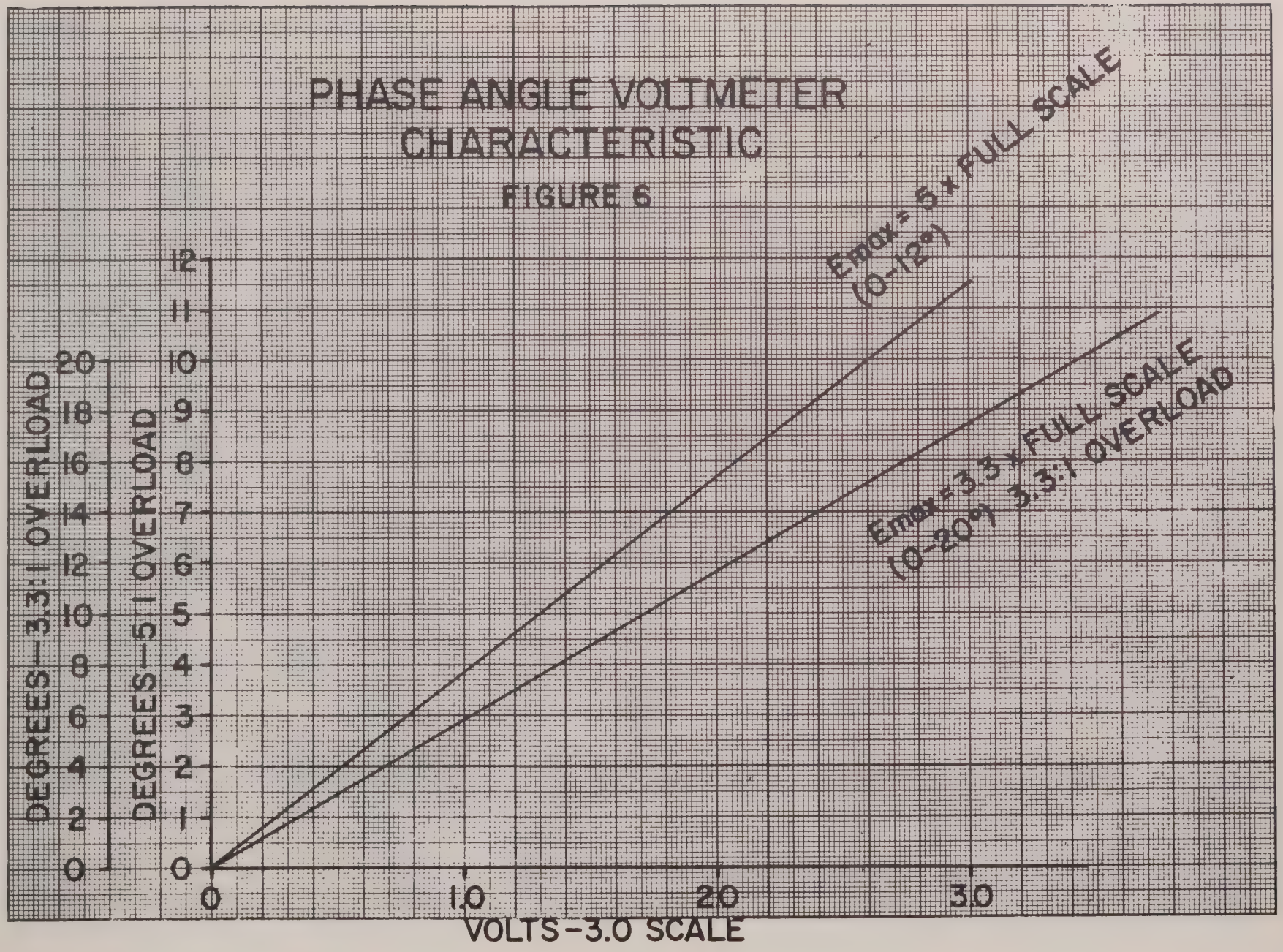

PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 6
Emax = 5 x FULL SCALE
(0-12°)
Emax = 3.3 x FULL SCALE
(0-20°) 3.3:1 OVERLOAD
DEGREES—3.3:1 OVERLOAD
DEGREES—5:1 OVERLOAD
0
2
4
6
8
10
12
14
16
18
20
0
1
2
3
4
5
6
7
8
9
10
11
12
0
1.0
2.0
3.0
VOLTS—3.0 SCALE

TABLE II

Max. Voltage	Scale for meas. deg.	Full Scale Overload Ratio	Degree Range	Max. Error 3%	Figure
1.0	1.0	1:1	$\pm$ 90	2.7 deg.	5
1.0	.3	3.3:1	$\pm$ 19.5	0.6	6
1.0	.1	10:1*	$\pm$ 5.7	.2*	5
1.5	1.0	1.5:1	$\pm$ 41.8	1.3	5
1.5	.3	5:1	$\pm$ 11.5	.33	6

*NOTE: The overload alarm will be lighted when operated under these conditions. Saturation errors exist and for that reason no error rating is made.

High accuracy Phase Angle Measurements to better than .01° can be made using the alternate methods discussed in Section VIII under Small Angle Measurements.

IV-PHASE ANGLE MEASUREMENTS USING CALIBRATED PHASE SHIFTER

The built in calibrated phase shifter can be used to measure phase angle directly simply by shifting the reference by an amount equal to the phase angle being measured so as to produce a maximum meter reading in accordance with equation (1). Precise determination of the maximum point is difficult due to the zero slope of the phase characteristic at $\theta = 0$ deg. To avoid this difficulty, the instrument is equipped with four scales 90 degrees apart. Thus, by simply switching the reference 90 degrees the phase shifter dial can be readily set to a zero point on the meter and then by switching back to the original quadrant the unknown phase angle can be read.

This procedure allows the measurement of phase angles from 0 to 360 degrees. Ambiguity which exists for two quadrants is easily removed by adding 180 degrees to the dial reading if a negative maximum (meter deflection to the LEFT) is used for the measurement. For positive maximums (meter deflections to the RIGHT) the dial scales apply directly.

V-MEASUREMENT OF QUADRATURE AND IN-PHASE COMPONENTS OF A SIGNAL

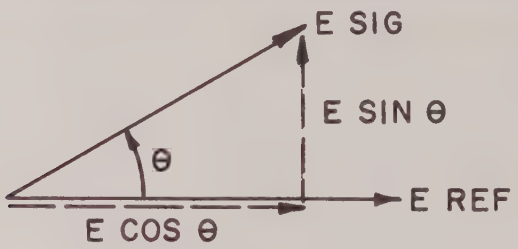


FIG. 7

The quadrature and in-phase components of a signal are defined in accordance with the diagram of Figure 7 as:

In-phase component = E cos θ

Quadrature Component = E sin θ

Measurement of the in-phase component is made by placing the Phase Angle Dial at zero degrees and reading the meter directly. This voltage will be E cos θ. (Function Selector must be in one of the PHASE ANGLE VTVM positions). By switching the Function Selector to an adjacent quadrant, the reference is shifted 90 degrees and the meter now reads the quadrature component of voltage E sin θ. For the greatest accuracy in this type of measurement the null or 90 degree point should be calibrated on the scale in which the voltage component is to be read. See the section under PHASE CHARACTERISTIC for a description of this type of adjustment.

VI-MEASUREMENT OF POWER FACTOR AND IMPEDANCE ANGLE

Both power factor and impedance angle are defined as the angle which a current vector makes with the voltage reference. This measurement is conveniently accomplished by means of the set-up shown in Figure 8. The angle is measured as previously discussed.

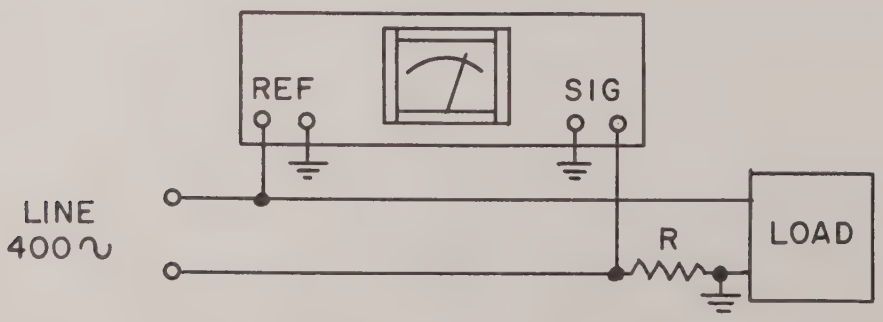


FIG. 8

VII-IMPEDANCE MAGNITUDE

The magnitude of any impedance is measured by using the "STD VTVM" portion of the instrument. Figure 9 illustrates the manner in which the measurements can be made.

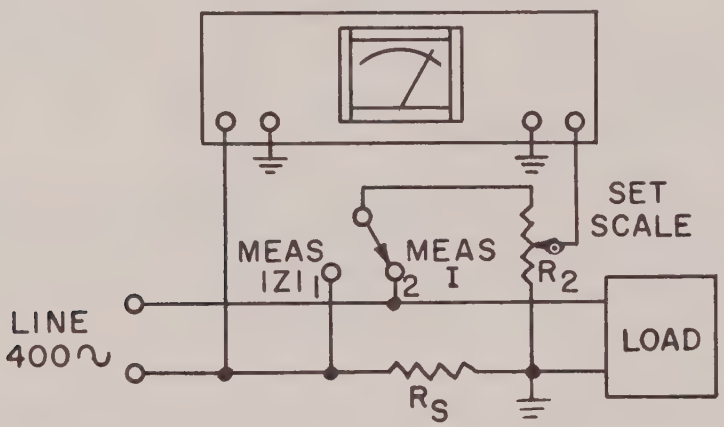


FIG. 9

Using Table III as a guide, a precision ($\leq$ 1%) resistor of convenient size is selected for Rs. With S1 in position 1 for measuring current, adjust the scale set potentiometer to read full scale volts on any 10 scale. Note the actual voltage value. Switch S1 to position 2 for measuring /Z/ and read the meter. This reading will be the impedance magnitude expressed in units of kilohms, ohms, hundreds of ohms, milliohms, etc. depending upon the value of Rs series resistance used per Table III and when divided by the current measurement noted above.

EXAMPLE

Load Impedance = 470K

Rs = 1K

E line = 115 volts

With S1 in position 1 set the level using R2 to a convenient full scale of 10. This might be 0.1 volts. Switching then to position S2 will produce a meter deflection of 47K on the 100K scale (100 volts scale is now 100K per Table III). Dividing this by the current scale of 0.1 will yield 470K. Since the current factor is always set at a multiple of 10, this last correction is simple to accomplish.

TABLE III

Series Resistor	Scale 1 Volt Equals	Current Factor
10K	10K	1/volts
1K	1K	"
100 ohms	100 ohms	"
10 ohms	10 ohms	"
1 ohm	1 ohm	"

Measurement of A.C. Resistance and Reactance

By using the circuit of Figure 9 the real and imaginary components of the impedance can also be measured directly by using the current as a referency and measuring the in-phase and quadrature components of the signal measured with the switch in position 2. The in-phase component will be the A.C. Resistance and the quadrature component will be the reactance with the sign determined as positive for a right hand meter deflection and negative for a left hand deflection.

The following series of block diagrams will illustrate how this instrument can be applied to some of the specific applications noted earlier.

VIII-APPLICATIONS

Precision Ratiometer

In many analogue computer systems the process of multiplication, division, addition and subtraction is accomplished using precision potentiometers, or resistors. Those applications involving extremes of precision must be concerned with the distributed capacitance of the circuit element. Ordinary nulling system, for example, will not permit the manufacture of very precise resistors because of the errors masked by quadrature signals. The circuit of Figure 10 permits precise zeroing of pots or matching and calibration of resistors and potentiometers independent of stray capacitances, or harmonics in the signal source.

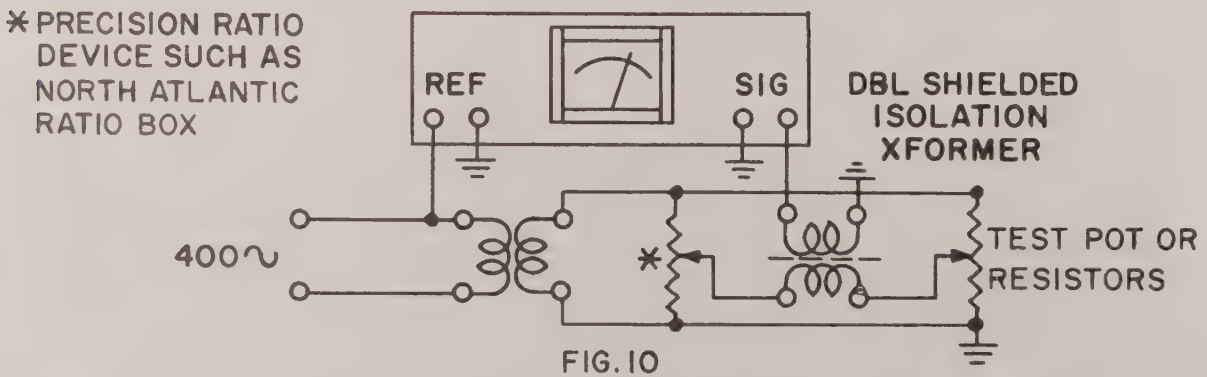


FIG. 10

Two isolation transformers are actually not necessary. If the source is to be isolated then an inexpensive transformer can be used. If the outputs are to be isolated then a low capacitance transformer such as a North Atlantic T-110 should be used. An alternate arrangement would be the circuit of Figure 11, which uses a summing network.

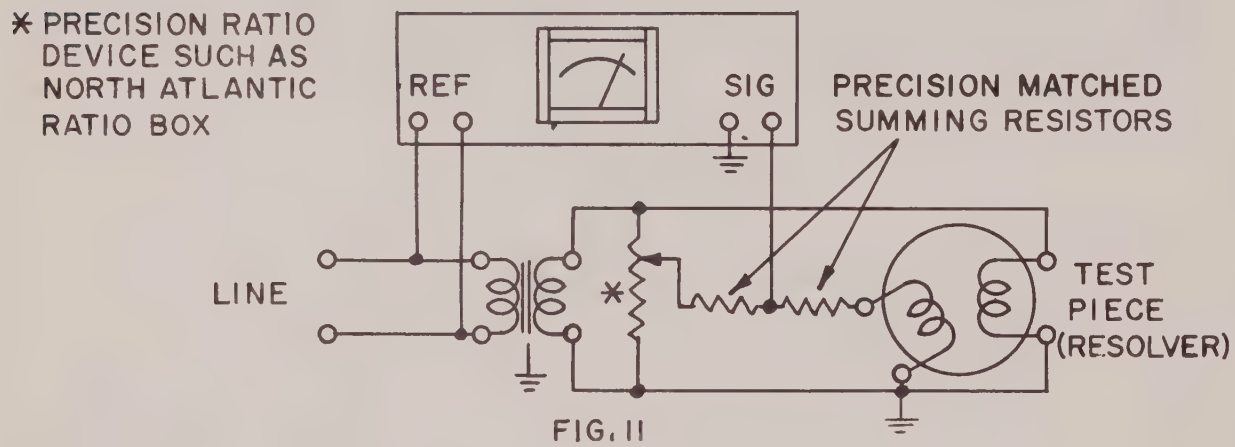


FIG. 11

Transducer Nulling

Applications involving transducers such as differential transformers or E-Coil pickoffs are extremely difficult to zero due to the large residual null voltage composed of signal and harmonics from the source as well as harmonics generated in the transducer. Figure 12 shows a system in which a precise in-phase balance can be achieved in the presence of quadrature and harmonics equal to 10 times the full scale sensitivity used. An order greater accuracy in nulling is easily achieved over conventional nulling circuits.

In addition, phase compensation for servo systems or for purposes of linearity compensation are easily accomplished using variations of this same test set-up.

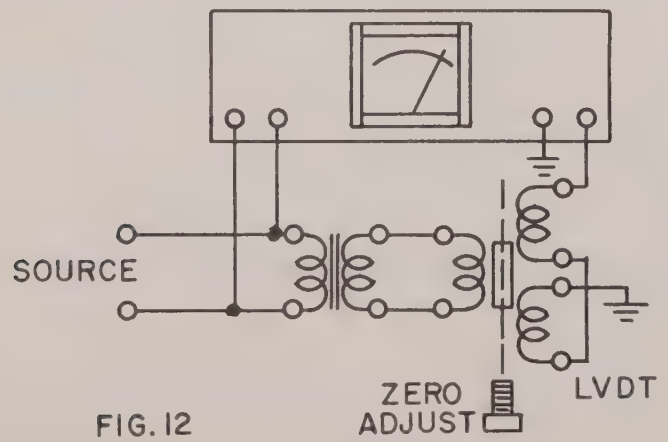


FIG. 12

Synchro Bridge Null Detector

When measuring the electrical errors of synchros, a circuit such as that shown in Figure 13 is used. The phase sensitive characteristics of the Phase Angle Voltmeter as well as the harmonic rejection of the filters and detector makes possible precision nulls unobtainable by conventional instrumentation.

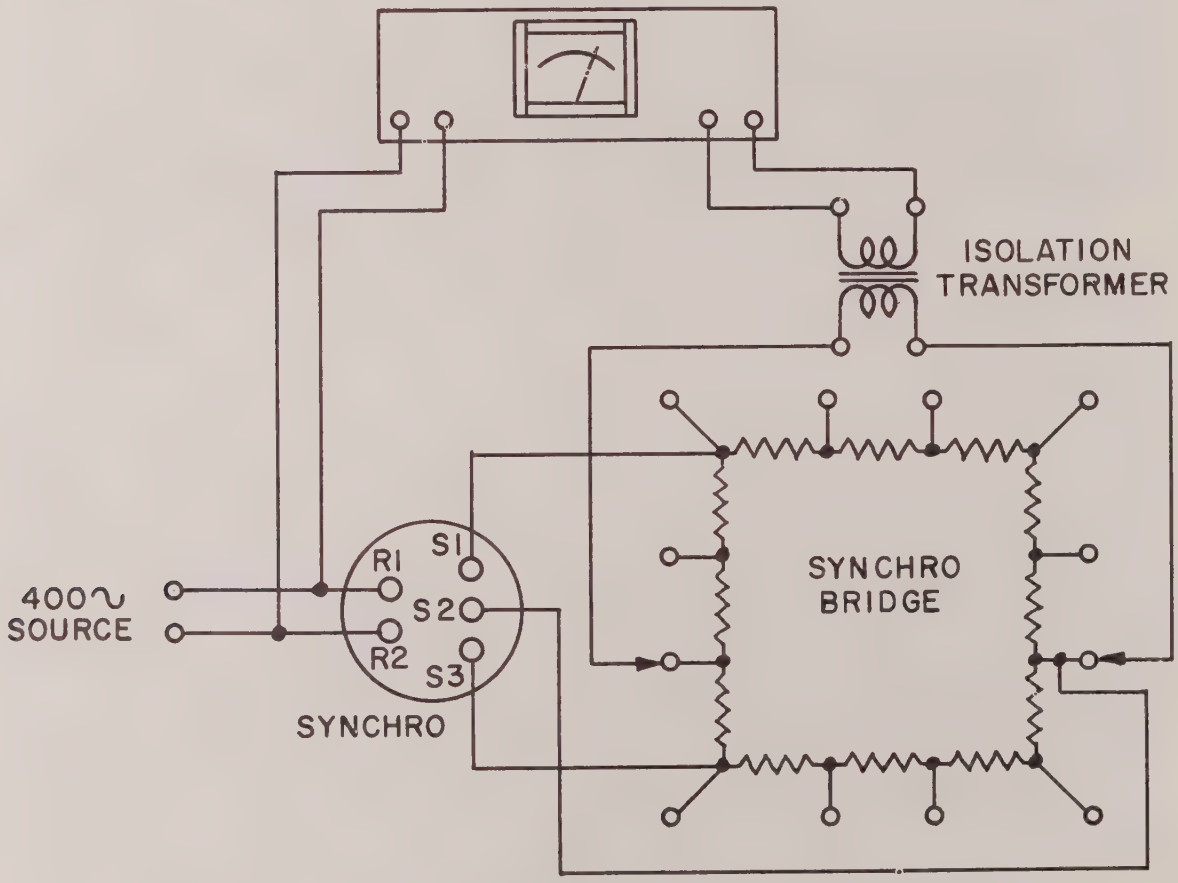


FIG. 13

Magnetic Amplifier and Thyratron Circuit Alignment

Circuits using thyratron power stages or magnetic amplifier stages cannot be monitored using conventional instruments because measurement errors can be prohibitively large due to the chopped wave forms. If the Phase Angle Voltmeter is used to monitor the output of such devices as shown in Figure 14, the task of alignment for maximum torque or output is straight forward since the meter reading is equivalent to motor output.

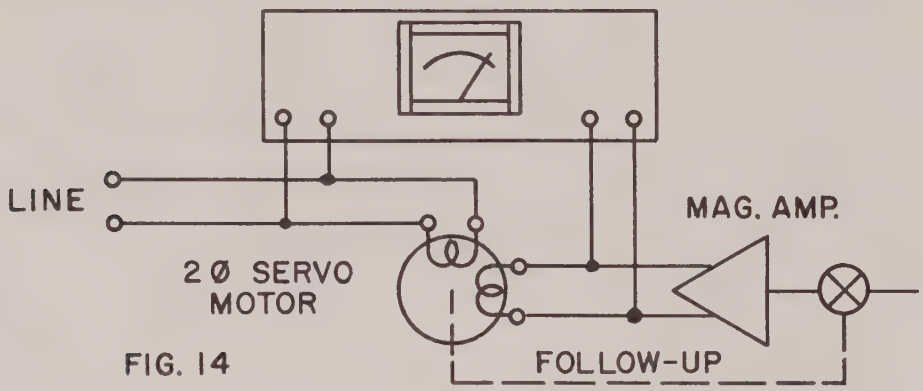


FIG. 14

Carrier Circuits and Amplifiers

Circuits such as those used for phase compensation, summing circuits, amplifiers, etc. must frequently be aligned to reduce quadrature effect to an acceptable minimum and to establish transfer functions at precise values of Phase Angles. Figure 15 is a test set-up used to check the phase angle transfer characteristic of a 400 cps carrier amplifier. Switch, S1, is used to adjust exactly the 90 degree point. A precision of trim to a fraction of a degree can be obtained.

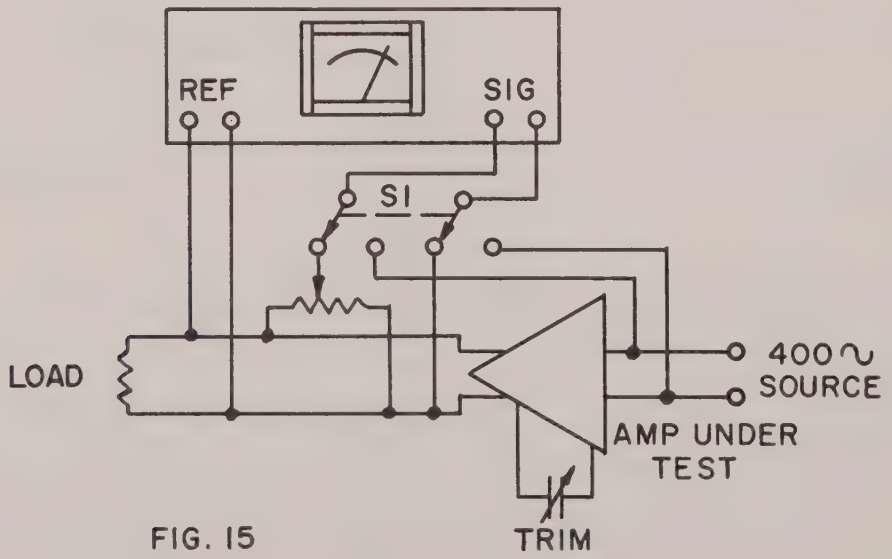


FIG. 15

TRANSFORMATION RATIO

Numerous circuit arrangements are used in making transformation ratio measurements. Two of the most practical are shown in Figure 16 (a) and 16 (b).

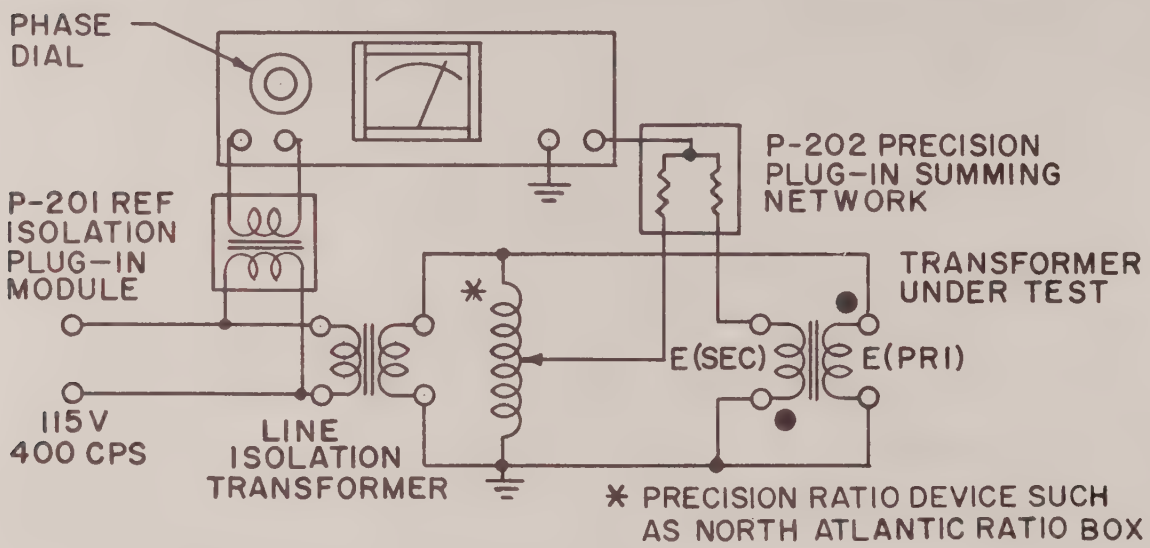


FIGURE 16(a)

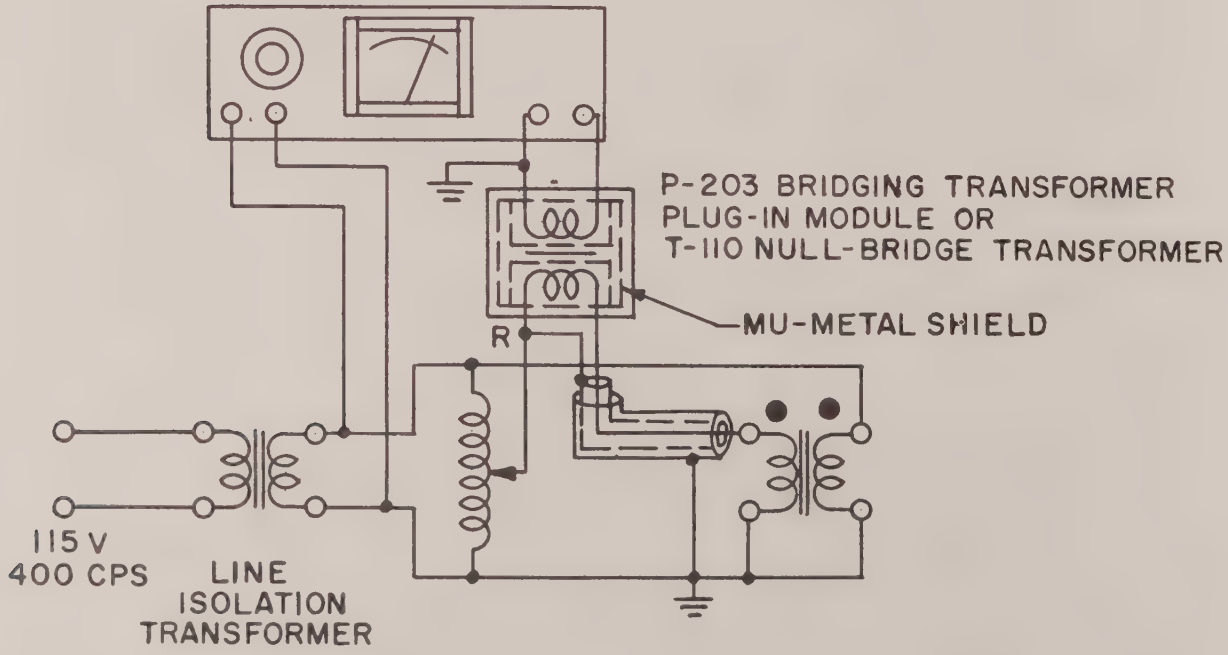


FIGURE 16(b)

I. SUMMING NETWORK TECHNIQUE

In Figure 16 (a) the output of the test piece is arranged to have a polarity opposite to that of the ratio device. By means of precision summing resistors - available from NORTH ATLANTIC as the P202 PLUG-IN SUMMARY MODULES, the outputs are added. At null the ratio device will then read the in-phase ratio of the item under test. In this particular test set up a line isolation transformer is utilized so as to avoid grounding one side of the line. For illustrative purposes the NORTH ATLANTIC P-201 PLUG-IN REFERENCE ISOLATION MODULE is also shown as providing circuit isolation on the reference input. This feature can also be built into the voltmeter.

In using the circuit of Figure 16 (a) care should be exercised in evaluating the errors which can arise due to loading of the test piece by the summing resistors and inaccurate summing due to test piece source impedance.

Phase angle is easily measured using the technique shown in the following section for small angle measurement. Allowance must be made in this case for the 2:1 change in voltmeter sensitivity resulting from the summing network.

II. BRIDGING TRANSFORMER TECHNIQUE

For greater accuracy, the circuit of Figure 16 (b) has found wide acceptance where the requisite polarity arrangement is feasible. In this case, matching of the test piece output to the ratio device is achieved by using a bridging transformer. A NORTH ATLANTIC P203 BRIDGING TRANSFORMER MODULE is shown, although any good double-shielded isolation transformer with suitable common mode rejection and low input capacitance would suffice.

Measurement errors in Figure 16 (b) can occur due to capacitive loading of the test piece or capacitive coupling of the common mode signal into the secondary. The former can be minimized where shielded cables are used by using the so called "driven shield" technique shown in the figure.

Common mode rejection is a function of the transformer shielding, the impedance level of each input to the transformer and the relative values of these impedances. Each set up must be judged by itself as to its suitability for a particular measurement.

Phase angle again is easily measured using the small angle measuring technique shown in the following section. Here allowance must be made for the bridging transformer transformation ratio (1:1 for the NORTH ATLANTIC P203 MODULE).

Both of the above measuring systems are used to provide a direct reading of in-phase ratio. Transformation ratio is by definition the ratio of the absolute magnitude of the secondary to primary voltage. To obtain "transformation ratio" the "in-phase" ratio must be divided by the cosine of the phase shift angle.

Maximum accuracies for both set-ups require that the phase dial be adjusted to compensate for residual phase shifts arising from the various transformers in the system, etc.. This is conveniently done by stepping the ratio device and adjusting the phase dial to produce zero output when the function selector is in the 90° position. Operation will then be correct when the function selector is returned to the 0° position.

Small Angle Measurements

Small angle measurements to better than .01° can also be made using the set ups of Figure 16. The process consists of making the in-phase null, described in the foregoing, using the precision ratio device. Then, by definition the phase shift angle α is:

$$\alpha = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E sec}|} = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E pri}| \times \text{Ratio}}$$

By measuring the magnitude of the secondary voltage and the quadrature component of the input signal, the angle α can be determined.

For Example:

Measured quadrature = 30.0 millivolts

Secondary voltage = 30 volts

$$\alpha = \text{Tan}^{-1} \frac{0.03}{30}$$

$$\cong \frac{0.03}{30} = 0.001 \text{ Rad}$$

$$\equiv 0.001 \times 57.3 = .057 \text{ degrees}$$

WARRANTY

North Atlantic Industries, Inc. hereby warrants that this instrument is free from defects in material and workmanship. Liability under this warranty is limited to servicing, calibrating and replacing any defective parts with the exception of electron tubes and fuses if, within one (1) year after shipment the original purchaser notifies North Atlantic Industries, Inc. that the instrument is defective. Notification to the Sales Order Department of North Atlantic Industries, Inc. should give full details of the defect, including model and serial number of the instrument. Purchaser shall then await servicing or shipping instructions from North Atlantic Industries, Inc.

North Atlantic Industries, Inc. will repair and pay transportation charges of any instrument that is found defective during the period of our warranty. This shall be subject to the condition that there is no evidence that the instrument has been operated beyond its design range, has been improperly tested, or has been opened, disassembled, modified, dropped or tampered with in any way.

In the event that repairs are necessary which are not covered by the warranty, an estimate of costs to be incurred will be submitted for written approval before any work other than determining the defect is undertaken.

In-warranty repairs will be returned, transportation paid, by the original methods of shipment. Repairs not covered by the warranty will be returned in accordance with purchaser's instructions submitted with approval of repair charges.

North Atlantic Industries, Inc. shall not be liable for damage or injury to persons or property resulting from the operation of the instrument.

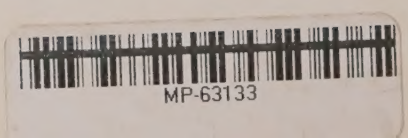
NOTE

This instrument has been carefully checked and packaged prior to shipment. Any loss, damage, or delay in shipment should be reported to the carrier. Further, if upon receipt the instrument fails to operate properly, or is damaged in any way, a claim should be filed with the carrier claim agent and forwarded to North Atlantic Industries, Inc., who will advise disposition and arrange for repair or replacement of the instrument.

In line with North Atlantic Industries' policy of prompt service to all customers, every effort will be made to repair and return any instrument as rapidly as possible.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. *overbrook 1-8600*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